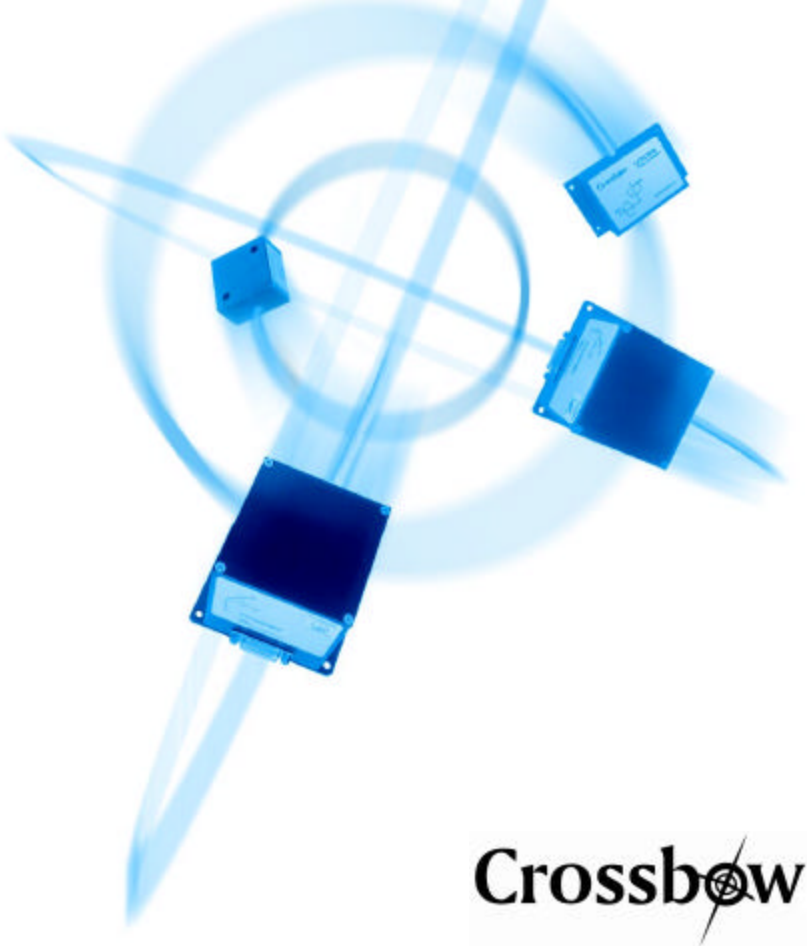
MTS/MDA Sensor and Data Acquisition Boards User's Manual

MTS101CA, MTS300CA, MTS310CA

Rev. A, April 2003

Document 7430-0020-01



Crossbow

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1 Introduction

The MTS Series of Sensor Boards are designed to interface with Crossbow's MICA, MICA2, and MICA2DOT family of wireless motes. There are a variety of sensor boards available, and the sensor boards are specific to the MICA, MICA2 board or the MICA2DOT form factor. The sensor boards allow for a range of different sensing modalities as well as interface to external sensor via prototyping areas or screw terminals. The following table lists the currently available sensor boards for each mote family.

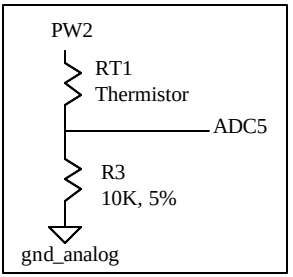
Part Number	Mote Support	Sensors
MTS101CA	MICA, MICA2	Light, Temperature, Prototype Area
MTS300CA	MICA, MICA2	Light, Temperature, Acoustic, and Sounder
MTS310CA	MICA, MICA2	Light, Temperature, Acoustic, Sounder, 2-Axis Accelerometer (ADXL202), and 2-Axis Magnetometer
MDA500CA	MICA2DOT	General Purpose Interface

2 MTS101CA

The MTS101CA series sensor boards have a precision thermistor, a light sensor/photocell, and general prototyping area. The prototyping area supports connection to five channels of the Mote's A-D Converter (ADC3-7) and the I2C digital communications bus. The prototyping area also has 24 unconnected holes that are used for breadboard of circuitry.

2.1 Thermistor

The Thermistor, (YSI 44006, http://www.ysi.com) sensor is a highly accurate and highly stable sensor element. With proper calibration, an accuracy of 0.2°C can be achieved. The Thermistor resistance varies with temperature (see Table and Graph). This curve, although non-linear, is very repeatable. The sensor is connected to the analog-digital converter channel number 5 (ADC5, U1 pin 38) thru a basic resistor divider circuit. In order to use the thermistor, the sensor must be enabled by setting digital control line PW2 high. See circuit below.



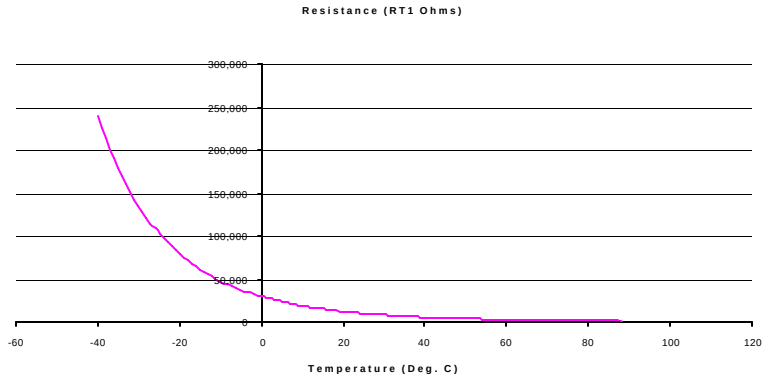
Thermistor Specifications:

Type:	YSI 44006
Time Constant:	10 seconds, Still Air
Base Resistance:	10Kohm, @ 25°C
Repeatability:	0.2°C

Voltage, Resistance vs. Temperature:

Example Temperature (°C)	Resistance (Ohms)	ADC5 Reading (% of VCC)
-40	239,800	4%
-20	78,910	11%
0	29,940	25%
25	10,000	50%
40	5592	64%
60	2760	78%
70	1990	83%

Resistance vs. Temperature Graph:



2.2 Conversion to Engineering Units

The mote's adc output can be converted to degrees Kelvin using the following approximation over 0-50 degrees C:
$1/T(K) = a + b*Ln(Rthr) + c*[Ln(Rthr)]^3$

where:

$Rthr = R1(ADC_FS-ADC)/ADC$

$a = 0.001010024$

$b = 0.000242127$

$c = 0.000000146$

$R1 = 10K$

$ADC_FS = 1024$

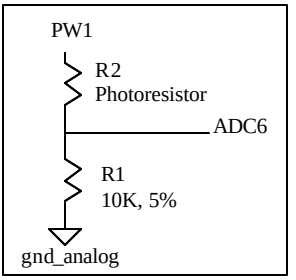
ADC = output value from mote's ADC measurement.

2.3 Light Sensor

The light sensor (Clairex CL94L, http://www.clairex.com) is a simple CdSe photocell. The maximum sensitivity of the photocell is at the light wavelength of 690 nm. Typical on resistance, while exposed to light, is 2Kohm. Typical off resistance, while in dark conditions, is 520Kohm. In order to use the light sensor, digital control signal PW1 must be turned on. The output of the sensor is connected to the analog-digital converter channel 6 (ADC6, U1 Pin 37). See Circuit Below.

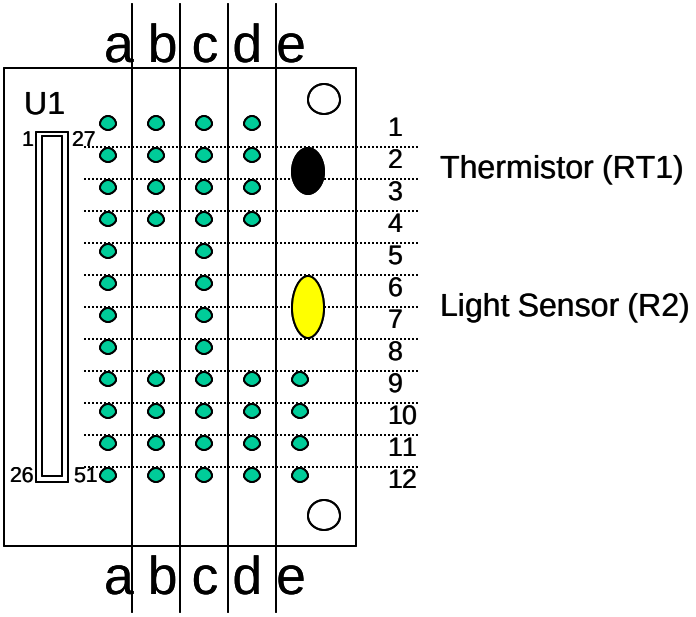
Light Sensor Specifications:

Type:	Clairex CL94L
Ron:	2 Kohm
Roff:	520 Kohm



2.4 Prototyping Area

The prototyping area is a series of solder holes and connection points for connecting other sensors and devices to the Mote. The prototyping area layout is shown in the diagram and tables below.



Connection Table (Top View of PCBA)

A1-A12 No Connect, Bare Hole

C1-C12 No Connect, Bare Hole

B1	PW4 (U1-33)	B9	I2C_BUS_DATA (U1-22)
B2	PW5 (U1-34)	B10	I2C_BUS_CLK (U1-21)
B3	PW6 (U1-35)	B11	FLASH_SO (U1-19)
B4	ADC3 (U1-36)	B12	FLASH_SI (U1-20)
D1	GND_ANALOG (U1-1)	D9	GND (U1-51)
D2	VDD_ANALOG (U1-2)	D10	VCC (U1-50)
D3	ADC1 (U1-42)	D11	No Connect, Bare Hole
D4	ADC2 (U1-41)	D12	No Connect, Bare Hole
E9	PW3 (U1-32)	E11	ADC0 (U1-43)
E10	ADC4 (U1-39)	E12	GND_ANALOG (U1-1)

NOTE

If you have downloaded the pdf schematic of the Rene basic sensor board from UC Berkeley, you will note that the A/D channels appear in reverse order. This is due to a difference in wiring between the original Rene Mote and the MICA/MICA2 family of motes.

WARNING

Never connect signals that are greater than VCC (3V typical) or less than 0V to any of the holes that connect to the Mote Processor Radio board. It is okay to connect different voltages to the non-connected holes. However, be careful. If a voltage out of the range of 0-VCC should reach the Mote Processor Radio Board damage will occur.

3 MTS300CA / MTS310CA

The MTS300CA and MTS310CA .are flexible sensor boards with a variety of sensing modalities. These modalities can be exploited in developing sensor networks for a variety of applications including vehicle detection, low-performance seismic sensing, movement, acoustic ranging, robotics, and other applications. The following section of the user's manual describes the sensor circuits and general application. Please refer to the schematic diagram at end of section for exact circuit details.

3.1 Microphone

The microphone circuit has two principal uses. The first use is for acoustic ranging. The second use is for general acoustic recording and measurement. The basic circuit consists of a pre-amplifier (U1A-1), second-stage amplified with a digital-pot control (U1A, PT2).

This circuit amplifies the low-level microphone output. This output can be fed directly into the analog-digital converter (ADC2) by using the Microphone Output selector circuit (MX1) to connect mic_out signal toe ADC2 signal. This configuration is useful for general acoustic recording and measurement. Audio files have been recorded into the Logger Flash memory of MICA, MICA2 Motes for later download and entertainment (or analysis!).

The second stage output (mic_out) is routed thru an active filter (U2) and then into a tone detector (TD1). The LM567 CMOS Tone Detector IC actually turns the analog microphone signal into a digital high or low level output at INT3 when a 4KHz tone is present. This tone can be generated by the Sounder circuit on the sensor board.

A novel application of the sounder and tone detector is acoustic ranging. In this application, a mote pulses the sounder and sends an RF packet via radio at the same time. A second mote listens for the RF packet and notes the time of arrival by resetting a timer/counter on its processor. It then increments a counter until the tone detector detects the sounder. The counter value is the Time-of-Flight of the sound wave between the two motes. The Time-of-Flight value can be converted into an approximate distance between motes. Using groups of Motes with Sounders and Microphones, a crude localization and positioning system can be built

◀ NOTE

Motes are designed for power efficiency. Hence all the sensors are disconnected from power on the MTS300 and MTS310 sensor boards unless specifically turned on. See section 3.6 for more information.

3.2 Sounder

The sounder is a simple 4KHz fixed frequency piezoelectric resonator. The drive and frequency control circuitry is built into the sounder. The only signal required to turn the sounder on and off, is Sounder_Power. Sounder_Power is controlled thru the power control switch (P1) and is set by the hardware line PW2.

3.3 Light and Temperature

As on the MTS101CA, the MTS300CA and MTS310CA have a light sensor and a thermistor.

The thermistor (Panasonic ERT-J1VR103J) on the MTS300CA and MTS310CA is a surface mount component installed at location RT2. It is configured in a simple voltage divider circuit with a nominal mid-scale reading at 25°C. The output of the temperature sensor circuit is available at ADC1. Power is controlled by setting signal INT2.

Voltage, Resistance vs. Temperature:

Example Temperature (°C)	Resistance (Ohms)	ADC1 Reading (% of VCC)
-40	427,910	2.3%
-20	114,200	8.1%
0	35,670	22%
25	10,000	50%
40	4090	71%
60	2224	82%
70	1520	87%

The light sensor (Clairex CL94L, http://www.clairex.com) is a simple CdSe photocell. The maximum sensitivity of the photocell is at the light wavelength of 690 nm. Typical on resistance, while exposed to light, is 2Kohm. Typical off resistance, while in dark conditions, is 520Kohm. In order to use the light sensor, digital control signal PW1 must be turned on. The output of the sensor is connected to the analog-digital converter channel 1 (ADC1). When there is light, the nominal circuit output is near VCC or full-scale, and when it is dark the nominal output is near GND or zero. Power is controlled to the light sensor by setting signal INT1.

NOTE

The light and temperature sensor share the same A/D converter channel (ADC1). Only turn one sensor on at a time, or the reading at ADC1 will be corrupted and meaningless.

3.4 2-Axis Accelerometer (MTS310CA Only)

The accelerometer is a MEMS surface micro-machined 2-axis, +/-2G device. It features very low current draw (<1mA) and 10-bit resolution. The sensor can be used for tilt detection, movement, vibration, and/or seismic measurement. The accelerometer, located at U5, is the ADXL202JE and the full datasheet is available at www.analog.com. A summary specification is provided for reference

Channels:	X (ADC3), Y (ADC4)	
G-Range:	+/- 2G	(1G = 9.8m/s^2)
Bandwidth	DC-50Hz	(controlled by C20, C21)
Resolution:	2mG (0.002G) RMS	
Sensitivity:	167 mV/G +/- 17%	
Offset:	2.5 V +/- 0.4V	

NOTE

The ADXL202 sensitivity and offset have a wide initial tolerance. A simple calibration using earth's gravitational field can greatly enhance the accuracy of the ADXL202 sensor. By rotating the sensor into a +1G and a –1G position, the offset and sensitivity can be calculated to within 1%.

3.5 2-Axis Magnetometer (MTS310CA Only)

The magnetometer circuit is a silicon sensor that has a unique bridge resistor coated in a highly sensitive NiFe coating. This NiFe coating causes the bridge resistance of the circuit to change. The bridge is highly sensitive and can measure the Earth's field and other small magnetic fields. A useful applications is vehicle detection. Successful test have detected disturbances from automobiles at a radius of 15 feet. The sensor is the Honeywell HMC1002 sensor. A detailed specification sheet is found at www.ssec.honeywell.com. The output of each axis (X, Y) is amplified by an instrumentation amplifier U6, U7. The amplified output is available at ADC5 and ADC6. Each instrumentation amplifier (U6, U7) can be tuned using the digital potentiometer PT1 that is controlled via the I2C bus.

NOTE

The NiFe core of the magnetic sensor is extremely sensitive. However, it is also subject to saturation. Saturation occurs when the sensor is exposed to a large magnetic field. Unfortunately the MTS310 circuit does not have an automatic saturation recovery circuit (set/reset). This limitation prevents the magnetometer from being useful in applications requiring DC response (for example compassing). There are four pads label S/R (Set/Reset) available on the PCB for adding an external set/reset circuit.

3.6 Turning Sensors On and Off

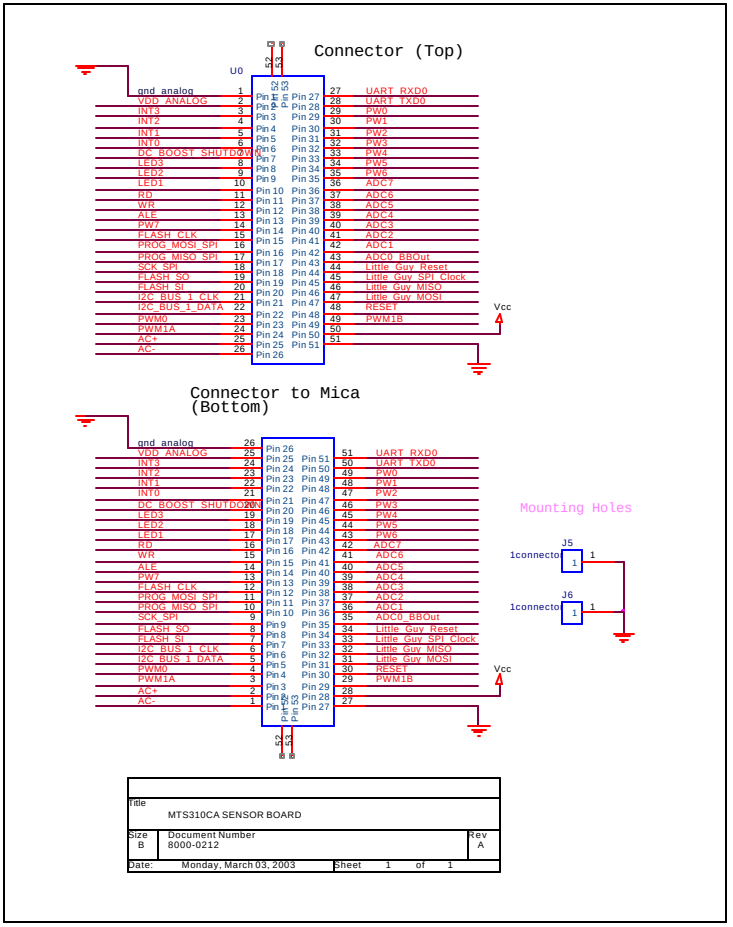
All of the sensors have a power control circuit. The default condition for the sensor is off. This design helps minimize power draw by the sensor board.

In order to turn sensors on, control signals are issued to the power switches. The following table lists the control settings

Sensor/Actuator	Control Signal
Sounder	PW2
Microphone	PW3
Accelerometer	PW4
Magnetometer	PW5
Temperature (RT2)	INT2
Photocell (R2)	INT1

Note only one of the INT1 and INT2 signals should be activated at a time. See Section 3.3

3.7 Schematic of the MTS300CA and MTS310CA



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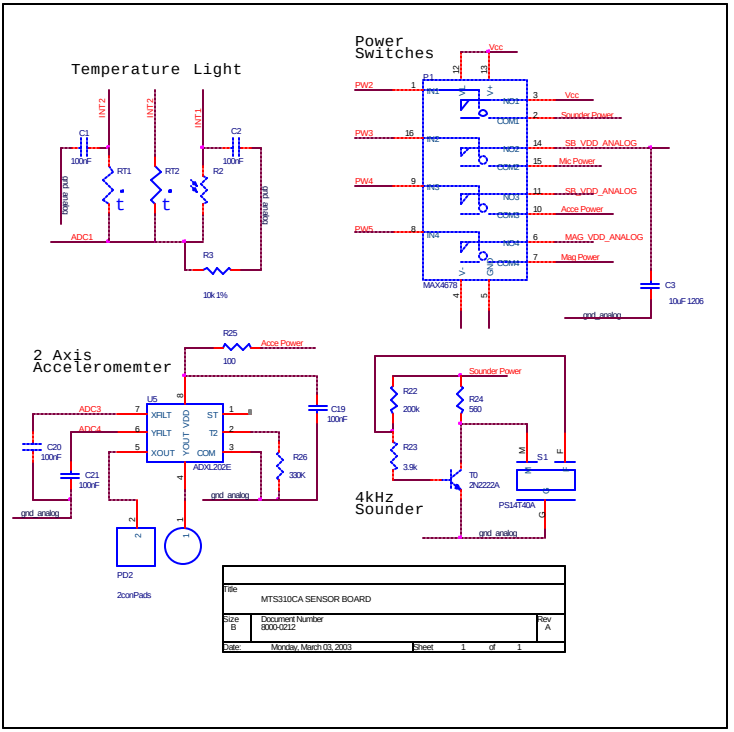
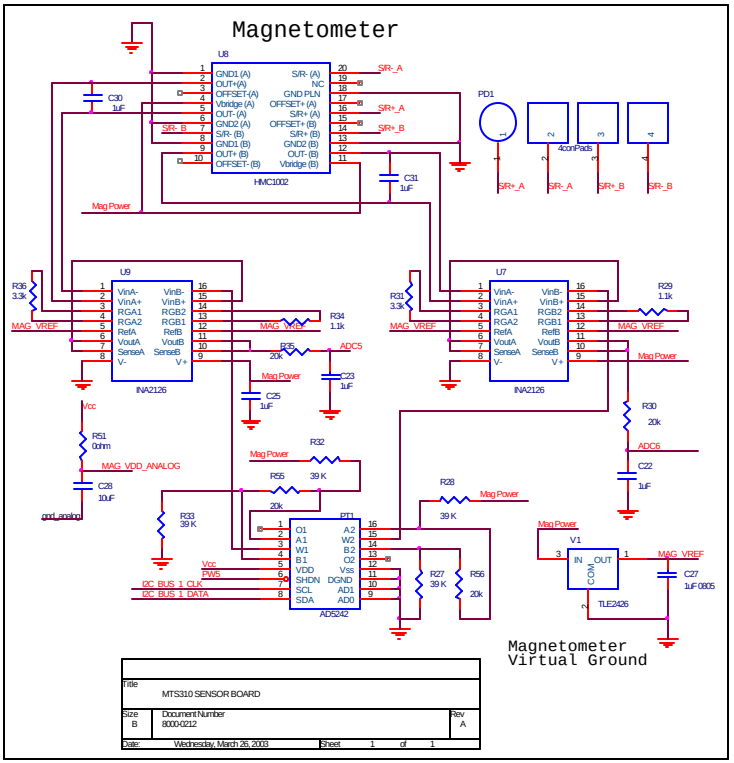

Temperature Light
Power Switches
2 Axis Acceleromemter
4kHz Sounder
Vcc
Sounder Power
SB_VDD_ANALOG
Mic Power
Acce Power
MAG_VDD_ANALOG
Mag Power
gnd_analog
MAX4678
ADXL202E
PS14T40A
2N2222A
MTS310CA SENSOR BOARD
Document Number 8000-0212
Monday, March 03, 2003


Magnetometer
U8
HMC1002
C30
1uF
C31
1uF
Mag Power
SR-_A
SR+_A
SR-_B
SR+_B
PD1
4conPads
U9
U7
INA2126
R36
3.3k
MAG_VREF
R34
1.1k
R35
20k
ADC5
C23
1uF
C25
1uF
R31
3.3k
R29
1.1k
R30
20k
ADC6
C22
1uF
Vcc
R51
0ohm
MAG_VDD_ANALOG
C28
10uF
gnd_analog
R32
39 K
R55
20k
R33
39 K
R28
39 K
PT1
AD5242
I2C_BUS_1_CLK
I2C_BUS_1_DATA
PWS
R27
39 K
R56
20k
V1
TLE2426
C27
1uF 0805
Magnetometer
Virtual Ground
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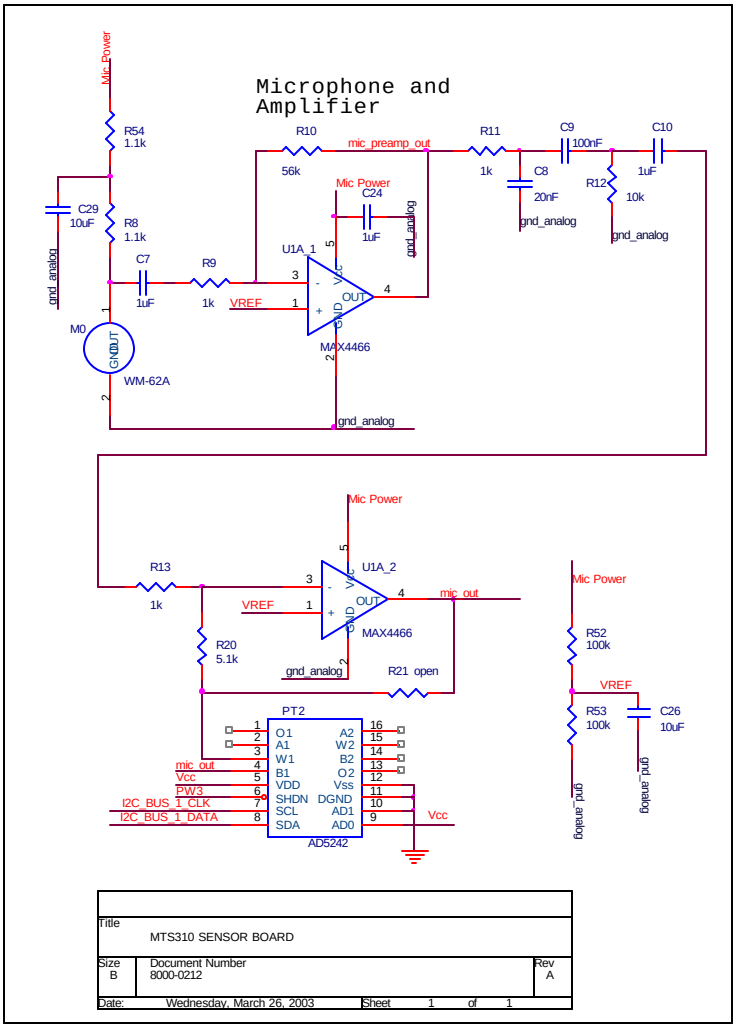
Microphone and Amplifier
Mic Power
R54 1.1k
C29 10uF
R8 1.1k
C7 1uF
R9 1k
VREF
M0
WM-62A
R10 56k
mic_preamp_out
C24 1uF
U1A_1
MAX4466
R11 1k
C9 100nF
C8 20nF
R12 10k
C10 1uF
gnd_analog
R13 1k
U1A_2
mic_out
R20 5.1k
R21 open
PT2
AD5242
I2C_BUS_1_CLK
I2C_BUS_1_DATA
Vcc
R52 100k
R53 100k
C26 10uF
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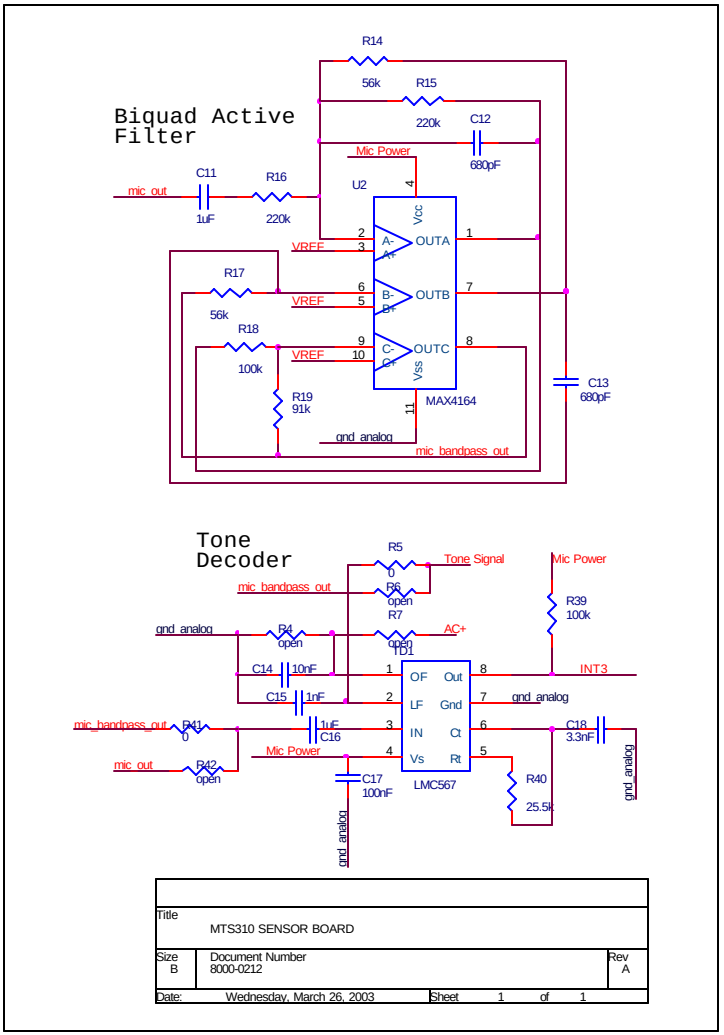
Biquad Active Filter
R14
56k
R15
220k
C12
680pF
Mic Power
C11
1uF
R16
220k
mic_out
U2
Vcc
A-
A+
OUTA
B-
B+
OUTB
C-
C+
OUTC
Vss
VREF
R17
56k
R18
100k
R19
91k
MAX4164
C13
680pF
gnd_analog
mic_bandpass_out
Tone Decoder
R5
0
Tone Signal
Mic Power
mic_bandpass_out
R6
open
R39
100k
gnd_analog
R4
open
R7
open
AC+
TD1
C14
10nF
C15
1nF
OF
Out
LF
Gnd
IN
Ct
Vs
Rt
INT3
gnd_analog
mic_bandpass_out
R41
0
C16
1uF
C18
3.3nF
mic_out
R42
open
Mic Power
C17
100nF
LMC567
R40
25.5k
gnd_analog
gnd_analog
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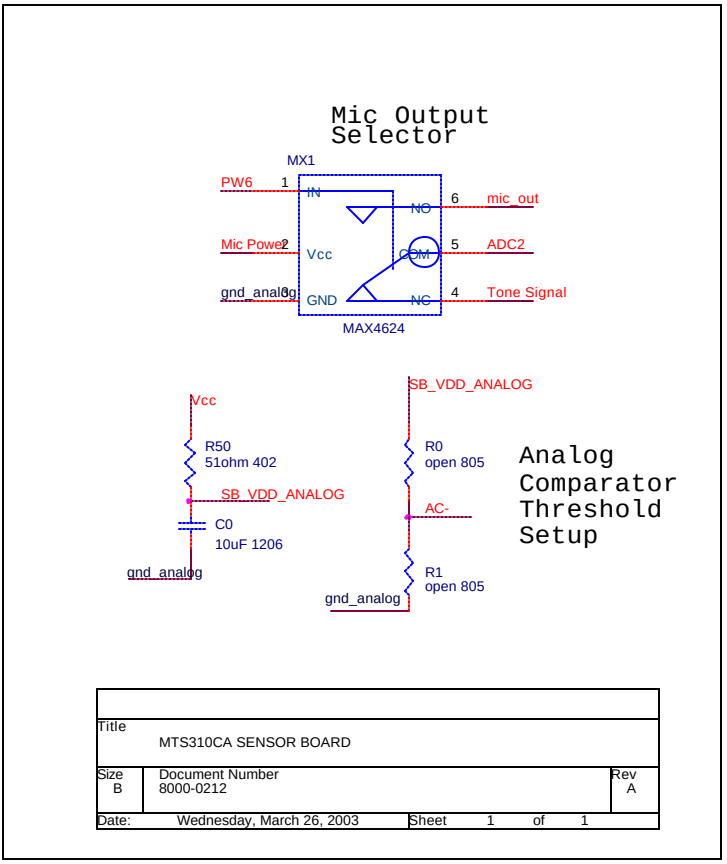
Mic Output Selector
MX1
PW6
1
IN
NO
6
mic_out
Mic Powe
2
Vcc
COM
5
ADC2
gnd_analog
3
GND
NC
4
Tone Signal
MAX4624
Vcc
R50
51ohm 402
SB_VDD_ANALOG
C0
10uF 1206
gnd_analog
SB_VDD_ANALOG
R0
open 805
AC-
R1
open 805
gnd_analog
Analog Comparator Threshold Setup
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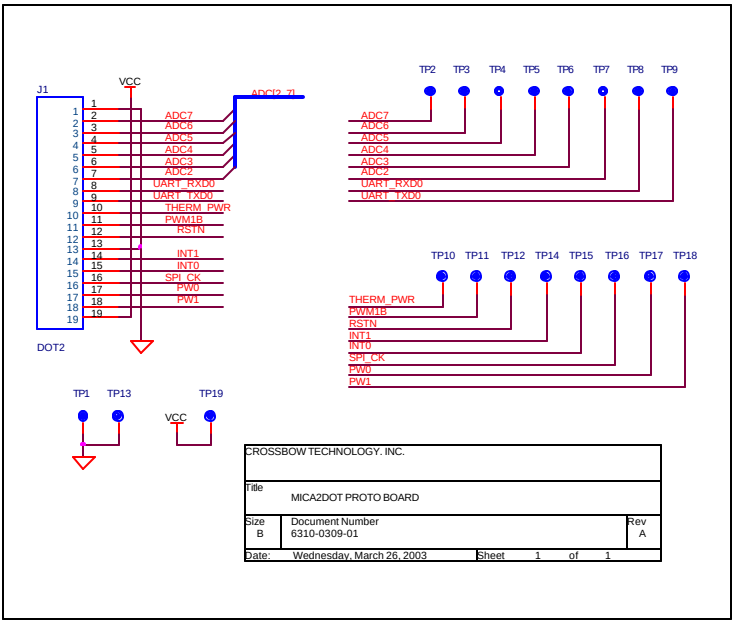
4 MDA500CA

The MDA500CA series sensor / data acquisition provides a flexible user-interface for connecting external signals to the MICA2DOT mote. All of the major I/O signals of the MICA2DOT mote are routed to plated thru holes on the MDA500CA circuit board.

4.1 Schematic



WARNING

Never connect signals that are greater than VCC (3V typical) or less than 0V to any of the holes that connect to the Mote Processor Radio board. It is okay to connect different voltages to the non-connected holes. However, be careful. If a voltage out of the range of 0-VCC should reach the Mote Processor Radio Board damage will occur.

5 TinyOS

This section describes how to compile different sensor boards with TinyOS.

In the tinyos-1.x/tos/sensorboards directory there are sub-directories for each supported sensor board:

Directory Name	Sensor Board	Description
/basicsb	MTS101CA	Basic sensor board
/micasb	MTS300CA MTS310CA	MICA sensor board
/micawb	not yet released	MICA weatherboard (humidity, temperature, barometric pressure, light)

Application code is linked to different sensor boards by modifying the make files in the application directories.

5.1 Building TinyOS Code with Sensor Board

To link a sensor board to the application code, edit the local Makefile (in your application directory). Modify the 'SENSORBOARD= ' line. For example, in the apps/MicaWBVerify/TestHumidity application the Makefile is:

```
COMPONENT=TestHumidity
SENSORBOARD=micawb
include ../../Makerules
```

6 Appendix D. Warranty and Support Information

6.1 Customer Service

As a Crossbow Technology customer you have access to product support services, which include:

- Single-point return service
- Web-based support service
- Same day troubleshooting assistance
- Worldwide Crossbow representation
- Onsite and factory training available
- Preventative maintenance and repair programs
- Installation assistance available

6.2 Contact Directory

United States:	Phone:	1-408-965-3300 (7 AM to 7 PM PST)
	Fax:	1-408-324-4840 (24 hours)
	Email:	techsupport@xbow.com
Non-U.S.:	refer to website	www.xbow.com

6.3 Return Procedure

6.3.1 Authorization

Before returning any equipment, please contact Crossbow to obtain a Returned Material Authorization number (RMA).

Be ready to provide the following information when requesting a RMA:

- Name
- Address
- Telephone, Fax, Email
- Equipment Model Number
- Equipment Serial Number
- Installation Date
- Failure Date
- Fault Description

6.3.2 Identification and Protection

If the equipment is to be shipped to Crossbow for service or repair, please attach a tag TO THE EQUIPMENT, as well as the shipping container(s), identifying the owner. Also indicate the service or repair required, the problems encountered, and other information considered valuable to the service facility such as the list of information provided to request the RMA number.

Place the equipment in the original shipping container(s), making sure there is adequate packing around all sides of the equipment. If the original shipping containers were discarded, use heavy boxes with adequate padding and protection.

6.3.3 Sealing the Container

Seal the shipping container(s) with heavy tape or metal bands strong enough to handle the weight of the equipment and the container.

6.3.4 Marking

Please write the words, "***FRAGILE, DELICATE INSTRUMENT***" in several places on the outside of the shipping container(s). In all correspondence, please refer to the equipment by the model number, the serial number, and the RMA number.

6.3.5 Return Shipping Address

Use the following address for all returned products:

Crossbow Technology, Inc.
41 Daggett Drive
San Jose, CA 95134
Attn: RMA Number (XXXXXX)

6.4 Warranty

The Crossbow product warranty is one year from date of shipment.

Crossbow Technology, Inc.
41 Daggett Drive
San Jose, CA 95134
Phone: 408.965.3300
Fax: 408.324.4840
Email: info@xbow.com
Website: www.xbow.com